Unmanned Microgravity Flight Program

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Current microgravity facilities are limited to a maximum of 5 seconds, except for the full-scale microgravity aircraft. Envisioned here is a small, unmanned aircraft that could fly 3.6- to 4.5-kg (8- to 10-lb) payloads in reduced-gravity trajectories for 12 to 15 seconds at a cost competitive to operating a drop tower. Lunar or Martian gravity profiles would also be targeted.

Initial Testing

Existing small, radio-controlled planes were equipped with accelerometers as an initial feasibility test and to identify areas of development (figure 1). The test data showed that even without telemetry, the pilot was able to fly parabolas "blind" and achieve +/- 0.1 g. The data also confirmed the need for an onboard computer and sensors to smooth out the remaining vibration.

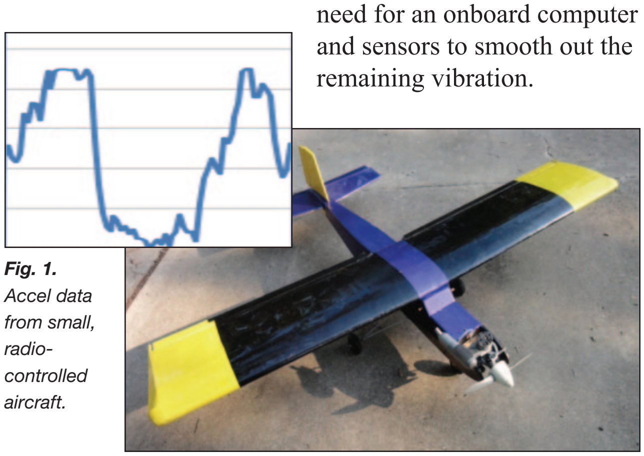

Fig. 1. *Accel data from small, radio-controlled aircraft.*

Airframe and Powerplant Selection

A study conducted by the European Space Agency (ESA) in 1995 provided useful recommendations and concluded that improved autopilots and powerplants, particularly a gas turbine, would be best suited for this type of mission, but were not readily available and/or cost-effective at that time. Fast forward 16 years, and a range of sensors and powerplants to test the feasibility have surfaced. To achieve the desired time in microgravity, projectile motion equations gave a vehicle speed of 305 km/hour (190 miles/hour). This resulted in gas turbines being the most viable powerplant option. A swept-wing design, retractable landing gear, autopilot, and large ruggedized airframe were selected on merit and budget, and aligned with ESA's recommendations. Ultimately, a TroyBuilt DV8R aircraft was selected and modified to accept an oversized KingTech K-170E gas turbine engine per the manufacturer's recommendation (figure 2). The aircraft has a wingspan of 210 cm (83 in.), length of 221 cm (87 in.), and a dry weight of 10 kg (22 lbs). The turbine weighs 1.6 kg (3.5 lbs) and produces 40 lbs of thrust at 123,000 rpm with an exhaust gas temperature of 700°C (1292°F). The engine runs on a mixture of Jet-A1 fuel and turbine oil.

Fig. 2. *DV8R "unmanned microgravity flight platform."*

Modifications

In addition to being modified to accept the larger turbine, several changes were made to the airframe. The landing gear hardpoints were reinforced to accept the heavier landing weights. All control surface hinges were reinforced and sealed to handle the expected high airspeeds. A more elaborate fuel delivery system was installed to deliver fuel to the turbine under microgravity conditions. A fully redundant flight control system was added to increase fault tolerance of the aircraft. Finally, the airframe was modified and aircraft systems were relocated to provide an internal volume

Fig. 3. *Payload module.*

that could accept a payload module (figure 3). The payload module (approximately the size of a shoebox) carries with it a 1080p digital video camera and light-emitting diode light to film experiments. Future payload modules could be custom built per the investigator's needs.

Autopilot

The need for a custom autopilot was anticipated. To save on development labor, a commercial off-the-shelf, open-source autopilot was selected (figure 4). The existing software would be sufficient for early phases of operation, while the open-source software could freely be modified for follow-on phases. The autopilot collects data from accelerometers, gyroscopes, a barometric altimeter, Global Positioning System receiver, magnetometer, and pitot-static pressure sensor. A separate microprocessor with watchdog reboots the primary processor in error scenarios. Data from the array of sensors are downlinked on a 900-MHz telemetry radio to drive cockpit instruments (including a g-meter) on the ground. As an added benefit, the autopilot supports a hardware-in-the-loop computer simulation to support development and testing of flight algorithms prior to any flight tests.

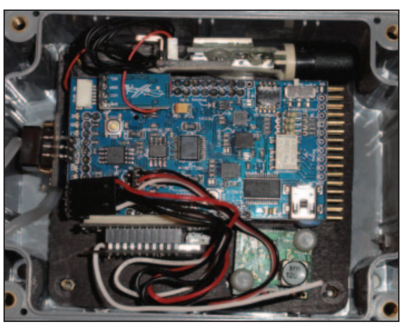

Fig. 4. *Autopilot/sensor suite.*

Phases of Operation

The flight test program is divided into three incremental phases of operation. In Phase I, the autopilot is downlinking telemetry, but it is not part of the flight control system. The aircraft is piloted manually according to flight instruments driven by downlink. A virtual cockpit with wraparound displays can give the pilot a point-of-view from the aircraft and display live flight instruments (figure 5). Phase II puts the autopilot in the flight control loops only for the roll and yaw axes to provide stability and to offload the pilot, allowing him or her to concentrate solely on flying the parabola via power and pitch modulation. Phase III gives the autopilot control of all axes while the pilot monitors, and can take control at any time. Phase III is expected to give the best results as the onboard autopilot will be able to compensate for local disturbances. Hardware simulations will be incorporated into all phases of operation.

Fig. 5. *Advanced Cockpit Evaluation System van wraparound display system.*

Flight Envelope Expansion

Because increasing microgravity time involves flying higher and faster, an incremental approach to increasing the safe flight envelope is desired. The versatility of the onboard computer makes it easy to add strain gauges to key aircraft components, such as the main wing spar, and downlink strain data live during flight. Such data could be compared to data from a failure-tested wing to determine definitive limits for speed and g-loading for this particular aircraft.

Conclusion

The aircraft is currently in the process of obtaining a flight clearance. Once granted, the plan is to progressively work through test Phases I, II, and III. This platform has interesting applications not only for science and engineering research, but also for public outreach and education. More experiments can be flown at a faster pace than with a human-rated aircraft. Less oversight is required for potentially dangerous payloads, such as those involving combustion. The aircraft is only limited by the size of the flight area and altitude, as determined by the parabola times needed. This opens up increased flight areas and flying out of remote venues can be considered.